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FIRE REGIME OF THE LODGEPOLE PINE FOREST OF MT. SAN JACINTO, CALIFORNIA

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ABSTRACT

The objective of this study of the 1000 ha lodgepole pine (*Piñus contorta* ssp. *murrayana*) forest of Mt. San Jacinto, California, is to typify several components of the fire regime, including intensity, size, frequency, and the relationship of fire with weather and its seasonal timing. We analyzed several lines of evidence, including fire occurrence from suppression records, fire dates from scarred *P. contorta* ssp. *murrayana,* forest structure as it relates to past disturbances, forest fuel loading, dendroclimatological modeling as it relates to past fire occurrences, and fire-igniting weather characteristics. The lodgepole pine forest of Mt. San Jacinto has a regime of fires that are typically of low intensity and that typically burn small areas (<10 ha). Lightning ignites fire somewhere within this forest as frequently as every few years, but given that lightning is a spatially random process and that fires typically burn areas less than 10 ha in size, the mean fire interval for any 10 ha area is more likely on the order of 100 years. Atypically large fires (20 ha or larger) are possible, but they have burned infrequently in the past. Fires appear to be more common during years when surface and ground fuels are relatively dry (a result of below-average winter precipitation), and fires occur primarily late in or after the growing season. Mt. San Jacinto State Park managers should always prepare for lightning fires, but they can probably safely allow most lightning fires to burn naturally within this ecosystem. Because the possibility exists for fires to burn large areas, fires should probably be monitored closely to protect a unique resource of very old *P. contorta* ssp. *murrayana* trees.

RESUMEN

El objetivo de este estudio en un bosque de mil hectáreas de *Pinus contorta* ssp. *murrayana* en Monte San Jacinto, California, es describir varios componentes del régimen de incendios, incluyendo la intensidad, el área, la frecuencia, las asociaciones entre incendios y el tiempo, y su sincronización estacional. Analizamos varias líneas de evidencia, incluyendo la ocurrencia de incendios según los registros de supresión, fechas de incendios según los pinos con heridas de incendio, la estructura forestal en relación a las pasadas perturbaciones, la cantidad de combustible forestal, modelos dendroclimatológicos en relación a pasadas ocurrencias de incendios, y las características climáticas iniciadoras de incendios. El bosque de *Pinus contorta* del Monte San Jacinto tiene un régimen de incendios que típicamente arden con una intensidad baja y en áreas menores de 10 ha. Los rayos inician incendios en cualquier parte dentro de este bosque con una frecuencia de 4 a 7 años, pero dado que los rayos que acompañan las tormentas son un proceso espacialmente al azar y que los incendios típicamente queman áreas menores de 10 ha, el intervalo promedio entre incendios en cualquier punto es probablemente del orden de 100 años. Incendios atípicamente grandes (decenas de hectáreas o más) son posibles, pero han ocurrido con poca frecuencia. Los incendios parecen ser más comunes durante años cuando los combustibles forestales en la superficie y el suelo están relativamente secos (a causa de precipitación invernal menor que la normal), y los incendios ocurren principalmente hacia el final o después del período vegetativo. Los guardabosques de Monte San Jacinto deben estar siempre preparados para incendios producidos por rayos, pero probablemente pueden permitir arder naturalmente la mayoría de estos incendios dentro de este ecosistema. Debido a que existe la posibilidad de incendios que queman áreas amplias, los incendios deben ser vigilados atentamente para proteger este recurso único de *Pinus contorta* longevos.

INTRODUCTION

The first step in formulating a fire management plan for a wilderness or natural area is determining the natural role of fire for the area (Agee 1974). Knowledge of the natural fire regime forms the basis for predicting fire behavior and responding to fires, helps illustrate the inevitability of fire in natural areas, and aids in the application and public interpretation of fire management plans (Mutch 1980). The (lodgepole pine) *Pinus contorta* ssp. *murrayana,* forest of the Mt. San Jacinto State Wilderness, California, has ample evidence of past fires in the form of abundant living, fire-scarred *P. contorta* ssp. *murrayana* located throughout the forest (Hamilton 1983). However, few of the details of the behavior of past fires can be inferred merely from the presence of fire-scarred trees. Our objective here is to typify several components of the regime of lightning-ignited fires of this forest, including intensity, size, frequency, the relationship of fire with weather, and seasonal timing of fires. To meet this objective, we analyzed multiple lines of evidence, including fire occurrence from suppression records, fire dates from scarred *P. contorta* ssp. *murrayana,* forest structure as it relates to past disturbances, forest fuel loading, dendroclimatological modeling

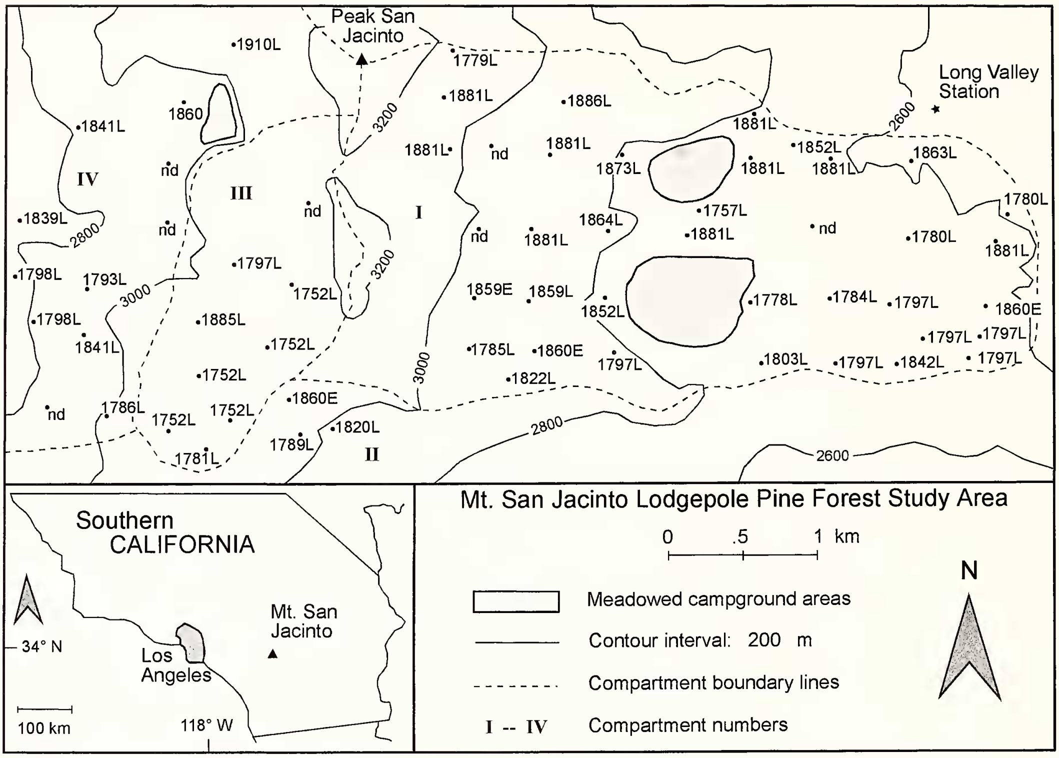

FIG. 1. Lodgepole pine forest of Mt. San Jacinto, Southern California. Dots mark plot locations, year values indicate the years when fire-scarred *P. contorta* ssp. *murrayana* were burned, and "nd" indicates fire-scar samples that were not crossdateable. "L" indicates a fire that occurred late in or after the growing season, and "E" indicates a fire that occurred early in the growing season; dates with neither letter indicate that the seasonal timing of the fire could not be unequivocally determined.

as it relates to past fire occurrences, and fire-igniting weather characteristics.

To accommodate the natural fire ecology of this lodgepole pine forest, Mt. San Jacinto State Park managers may use information from this study when formulating or amending policies for managing fire within their broader management goals of maintaining natural disturbance processes and protecting unique natural resources that include *P. contorta* ssp. *murrayana* up to several hundreds of years old (Hamilton 1983). This study also adds to the understanding of the ecology of *P. contorta* ssp. *murrayana* which occurs throughout the Sierra Nevada, Transverse, and Peninsular Ranges of California and in Baja California and is thought to have a stable ecological role and distribution that is not related to fire (Lotan and Critchfield 1990).

Materials and Methods

Study site. Mt. San Jacinto (33°49′N, 116°41′W) is 160 km east of Los Angeles, California (Fig. 1, inset). Between 2550 to 3200 m elevation *P. contorta* ssp. *murrayana* forms a xerophytic and depauperate forest (Thorne 1988) covering approximately 1000 ha. This forest is a topoedaphic climax with relatively minor amounts of other species (Hamilton 1983). At its lower elevations (2550 to 2900 m), *P. contorta* ssp. *murrayana* is mixed with *Abies concolor* (white fir), which extends to lower elevations beyond the range of *P. contorta* ssp. *murrayana*. At its higher elevations (2900 to 3200 m), *P. contorta* ssp. *murrayana* is mixed with *Pinus flexilis* (limber pine) in a sparse forest with an open canopy. The understory consists predominantly of *Ceanothus cordulatus* (snow bush) and *Chrysolepis sempervirens* (bush chinquapin).

Climate is mediterranean (cold, wet winters and warm, dry summers; Bailey 1966). Soils are derived from granitic parent material and are classified as lithic Xerorthents: They are shallow, coarse-textured with a large volume of rock fragments and outcrops, well drained, and very low in water holding capacity and fertility (Cohn, B. R. and J. G. Retelas, unpublished soil survey on file with the San Bernardino National Forest, California).

The fire regime and structure of this forest probably reflect little influence by Native Americans of the past. The Cahuilla Indians had the strongest presence in the study area (Smith 1957), but their main territory was the Cahuilla Valley at 1200 m elevation (Barrows 1900), considerably below the lodgepole pine forest. Summer and fall encampments were common in lower canyons (Aschmann 1959) but less common on higher ridges (James 1960; Bean and Saubel 1972). The Cahuillas rarely if ever used fire as a hunting aid (Drucker 1937).

Although there was some cattle grazing on Mt. San Jacinto, it ended by about 1940. Anecdotal accounts indicate that grazing was limited in the lodgepole pine forest and essentially restricted to the largest of the three meadow areas (Fig. 1; Hamilton 1983). While we recognize the potential impact of grazing on fire regimes of ecosystems in general (Savage and Swetnam 1990), we believe that the specific impact of grazing on the lodgepole pine forest of Mt. San Jacinto was not substantial.

Field sampling took place during the summers of 1983 and 1984. We divided the 1000 ha lodgepole pine forest study site into compartments by aspect (Fig. 1): Compartment I faces east, II faces south, III is a relatively flat plateau, and IV faces west. Meadowed campground areas were excluded because of the potential impacts of heavy recreational use on the fire regime, fuel loading, and forest structure. Within each compartment we located transects perpendicular to contours (Arno et al. 1993). Transects were 200 m apart, and sample points were 500 m apart along each transect. The fire-scarred *P. contorta* ssp. *murrayana* (Mitchell et al. 1983) nearest each sample point (usually no more than a few tens of meters away) was chosen as the center point for a 0.04 ha (20 m $\times$ 20 m) sample plot. Occasionally a plot contained more than one fire-scarred *P. contorta* ssp. *murrayana* up to five in one case.

For each plot, we recorded elevation, slope, and aspect, and we estimated forest fuel loading using a photo series of woody residues as quantified by Blonski and Schramel (1981) for this forest type. Within each plot, we measured diameter at breast height of all trees and counted trees, saplings, and seedlings shorter than breast height. We extracted increment cores from scarred *P. contorta* ssp. *murrayana* to dendrochronologically date the fires that caused the scars (Sheppard et al. 1988). We also cored old, unscarred *P. contorta* ssp. *murrayana* throughout the study site to develop a site- and species-specific reference chronology for crossdating purposes.

Analysis

Fire occurrence from suppression records. Although San Bernardino National Forest fire suppression records extend back to 1912, early records appear to be incomplete and we restricted this analysis to the period since 1945. We tabulated information on the suppression of lightning fires in the lodgepole pine forest of Mt. San Jacinto. We chronologically listed all years with at least one recorded lightning fire and calculated the mean time period between years when fires occurred.

Fire dates from scarred lodgepole pines. We crossdated (Stokes and Smiley 1968) cores from unscarred *P. contorta* ssp. *murrayana* (two cores per tree from twenty trees) and measured ring widths to the nearest 0.01 mm. We removed growth trends from each ring-width series by dividing each measurement by the corresponding value of a trend line estimated from either a modified negative exponential or a linear fit (Fritts 1976). We then autoregressively modeled the detrended series into residual series of white noise (Cook 1985), which were averaged into the reference index chronology. We verified the crossdating of this chronology against a tree-ring chronology from bigcone *Pseudotsuga macrocarpa* (Douglas-fir) growing 20 km from the study site (Keen Camp Summit, 33°43′N, 116°05′W, 1432 m elevation; Drew 1972).

Scarred trees were exclusively single-scarred, which allowed the effective use of increment cores to date the fires by crossdating ring-width series with the reference chronology (Sheppard et al. 1988). To establish the year of formation of the outermost ring before the fire, we crossdated non-disturbed ring growth that preceded the scar. Our crossdating of scarred samples was checked by another dendrochronologist. Additionally, we determined the general seasonal timing of the fire from the relative completeness of the outermost ring before the scar on samples for which this was possible (Baisan and Swetnam 1990). A complete or nearly complete ring (with at least some latewood cells) indicated a fire that burned after or late in the growing season (late July through early September). An incomplete ring (no latewood cells) indicated a fire that burned early in the growing season (early June through mid-July).

Pinus contorta *ssp.* murrayana *structure as related to disturbance regime.* We evaluated the histogram of diameters of sampled *P. contorta* ssp. *murrayana* from throughout the study site to determine the placement of this forest along the continuum of relatively even- to uneven- or all-aged structures (Hanley et al. 1975; Despain 1983; Lorimer and Frelich 1984). The use of diameters instead of actual ages requires that diameter and age be related such that age need not be determined for all trees sampled. To test for this relationship, we compared ages to diameters for a subset of *P. contorta* ssp. *murrayana* located throughout the study site for which pith dates were determined (Fig. 2). Based on this relationship, size is sufficiently related to age to use a histogram of diameters to characterize the age structure of *P. contorta* ssp. *murrayana* in this forest.

Relationship between fire occurrence and weather. We dendroclimatically modeled (Fritts 1976) the Keen Camp Summit tree-ring chronology with monthly weather data for the NOAA climatic division #7 (southeastern deserts) of California. This tree-ring chronology correlates well with precipi-

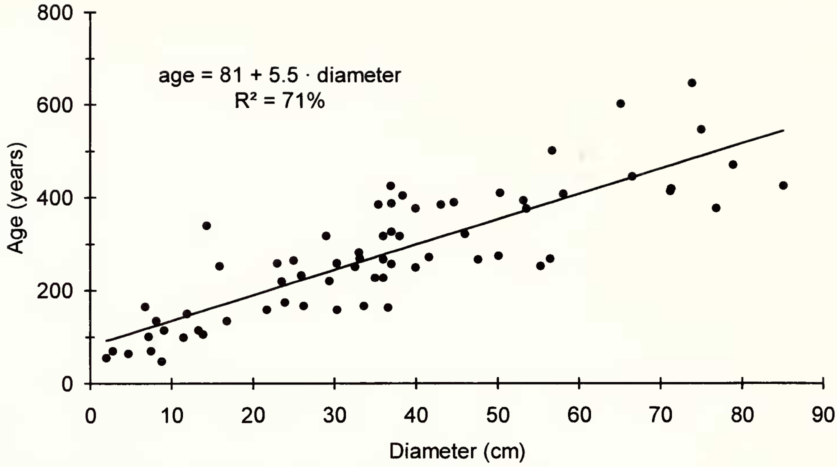

FIG. 2. Age-diameter relationship for *P. contorta* ssp. *murrayana* of Mt. San Jacinto.

tation of the winter prior to the growing season (Fig. 3a). When the December through March precipitation totals are summed, the winter season correlation with the chronology is 0.60 ($P < 0.01$). We extended the Keen Camp Summit tree ring chronology, which ends in 1966, by appending to it an indexed series of winter (December through May) precipitation at Idyllwild, California (1700 m elevation, 8 km south of Peak San Jacinto). We then assessed the relationship between fire occurrence and winter precipitation by comparing the average chronology index value for years when fire occurred to the average index value for the chronology (1.0 by definition, Fritts 1976).

Seasonal timing of fire risk. We searched the daily weather records from the Long Valley Ranger Station (2585 m elevation; Fig. 1) and the Idyllwild Fire Station for evidence of lightning occurrence for the entire study site. Combining data from these two stations located on opposite sides of the study site accounted for the local and sporadic nature of summer convection storms. Mid-May through mid-September is the period of likely convection storms (Tubbs 1972), and any day within this period with data or comments about rain, thunder, or lightning was considered to have had lightning possible. We grouped counts of these days into half-month periods and averaged across years for which complete records exist for both stations (1965 to 1974 and 1979 to 1984).

RESULTS

Fire occurrence from suppression records. The mean time period between years with at least one suppressed lightning fire is 5.2 ± 1.1 years (all error estimates are 95% confidence intervals) for the 1000 ha lodgepole pine forest from 1945 to 1987 (Table 1). Notably, 6 distinct fires were recorded for 1972, including two within the same survey section (259 ha) on each of two different days. Most of the listed fires occurred after mid-July (81%). Furthermore, all of the listed lightning fires were declared as spot fires—less than 0.4 ha in size at the time they were suppressed.

Fire dates from scarred P. contorta *ssp.* murrayana. We were able to crossdate 56 (88%) of the scarring events that we sampled (Table 2). Within plots with more than one fire-scarred *P. contorta* ssp. *murrayana,* all crossdatable samples dated the fires to the same year. We were able to determine the season of scarring in 52 scar samples, most of which (92%) contain at least some latewood cells in the outermost prescar ring and thus indicate fires that burned late in or after the growing season (Fig. 1).

Many of the fires dated from scarred *P. contorta* ssp. *murrayana* appear to be independent of each other, either by date and/or location (Fig. 1). For example, the year 1860 is represented by four plots that are widely separated from one another. To quantify the degree of this independence, we compared fire dates within each pair of adjacent plots, and most pairs (79%) have fire dates that differ from one another. Most adjacent pairs with the same fire date are located within three different clumps in the study site: five 1797 dates are located in the southeastern edge of Compartment I, nine 1881 dates in the northern half of Compartment I, and five 1752 dates in Compartment III (Fig. 1).

Our collection of fire scars includes only one date in the 20th century (1910). The lack of fire scars dating in the 20th century contradicts the suppression record (Table 1), which indicates frequent natural fires during the 20th century, especially since 1945. We attribute this apparent inconsistency to a bias of sampling visually obvious, larger scars of fires that burned further back in time. These *P. contorta* ssp. *murrayana* respond to fire scarring

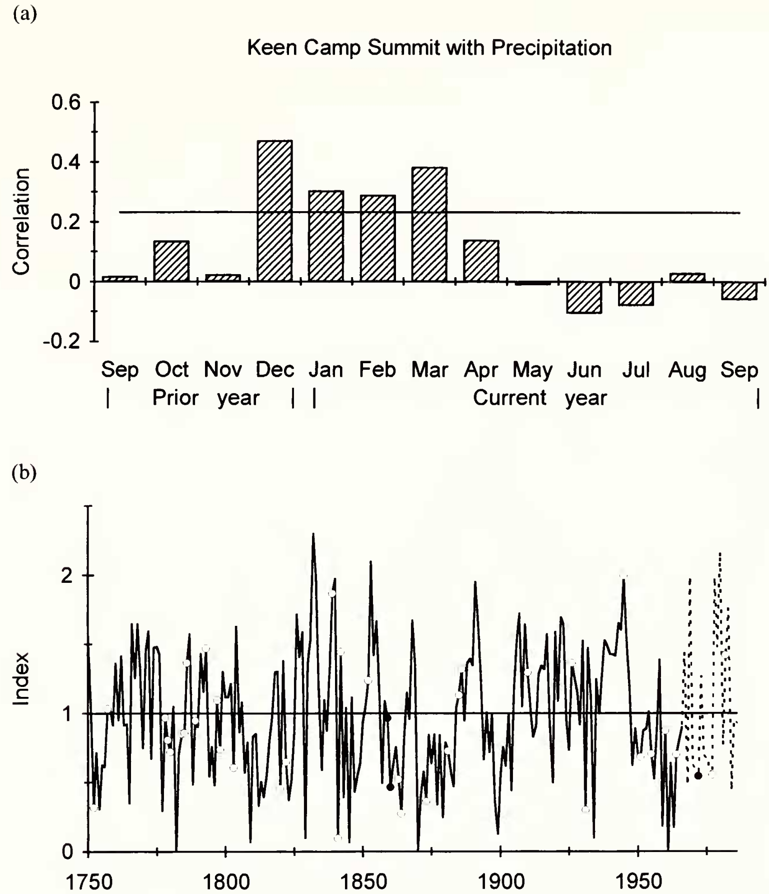

FIG. 3. (a) Correlations of the bigcone Douglas-fir index chronology from Keen Camp Summit to total monthly precipitation for NOAA climatic division 7 (southeastern deserts) of California. Reference lines indicate critical value for significance for alpha = 0.05, n = 71. (b) Winter (December through March) precipitation index chronology. The solid line (1750 to 1966) is the Keen Camp Summit chronology, the dashed line (1967–1986) is from the actual meteorological data from the Idyllwild station, and the reference line of 1.0 indicates average winter precipitation. Open dots indicate all years with evidence of fires, and closed dots indicate years with evidence of early-season fires.

with very slow growth rates after the scar, and scars from fires during the 20th century are small and inconspicuous such that we probably under-sampled them relative to older fire scars. Because of this sampling bias, we restricted our interval analysis of fire-scar dates to the period from 1752 to 1886, and the mean time period between years with fire anywhere in the 1000 ha forest is 5.0 ± 2.2 years (Table 2).

Pinus contorta ssp. *murrayana structure as related to disturbance regime.* The histogram of diameters of all sampled lodgepole pines is adequately fit by a negative exponential curve pattern (Fig. 4a). The three areas with several adjacent plots with the same fire dates (1752, 1797, and 1881; Fig. 1) warrant closer scrutiny, and we evaluated size histograms of *P. contorta* ssp. *murrayana* located within plots burned during those years. In the case of 1752, the size histogram is shaped broadly in a negative exponential pattern (Fig. 4b), and it has a slope coefficient that does not differ substantially from that of the *P. contorta* ssp. *murrayana* size histogram for the entire forest. In the case of 1797, the size histograms are not shaped in a negative exponential pattern (Fig. 4c). In the case of 1881, the size histogram is shaped broadly in a negative exponential pattern, but the number of individuals in the smallest size class is overestimated (Fig. 4d).

Forest fuel loading. The fuel loading within this lodgepole pine forest averages 18.9 ± 2.9 tonnes/ha, similar to the estimate of 15.4 tonnes/ha reported for a single area near the smallest meadowed campground area (Fig. 1; Compartment IV; Hanawalt and Whittaker 1976). The general fuel type of the lodgepole pine forest of Mt. San Jacinto is best described as Model H of the National Fire-Danger Rating System (Deeming et al. 1977), in which conifer trees pre-dominate; duff, litter, and branchwood are the primary ground fuels; and needles are less than 5 cm long. Additionally, as an indicator

TABLE 1. SAN BERNARDINO NATIONAL FOREST SUPPRESSION RECORDS (1912 TO 1989) OF LIGHTNING FIRES WITHIN THE LODGEPOLE PINE FOREST OF MT. SAN JACINTO[a]. All of these fires were listed as spots, smaller than 0.4 ha when suppressed. Mean time period between years with fire = 5.2 ± 1.1 years[d]. [a] The reports included all fires that burned within the San Jacinto District, but only lightning fires within the lodgepole pine forest were considered pertinent to this study. [b] All sections are approximately 259 ha (1 mi^2) and are within Township 4S, Range 3E of the San Bernardino Meridian. [c] This was not calculated for years prior to 1945 because of the incompleteness of the records for that time period. [d] For the period 1945 to 1987 and for the 1000 ha lodgepole pine forest.

Section location[b]	Date	Return interval (yrs)[c]	Section location	Date	Return interval (yrs)
27	August 4, 1926				8
			20	June 2, 1972	
29	September 4. 1931		21	June 2, 1972	
			21	June 2, 1972	
21	September 8, 1945		23	July 30, 1972	
		6	23	July 30, 1972	
21	September 28, 1951		23	July 31, 1972	
		4			5
23	August 14, 1955		23	August 16, 1977	
		5			5
23	September 7, 1960		22	July 25, 1982	
		4			5
30	July 26, 1964		21	September 1, 1987	

of the living fuel loading, the average stocking density of this forest is 375 ± 73 stems/ha for all species.

Relationship between fire occurrence and weather. For the period from 1752 (earliest fire-scar date) to 1986 (last year of our chronology of winter precipitation), fires have occurred only slightly more commonly during years of below-average winter precipitation (Fig. 3b). The average chronology index value for years with fire is 0.887 ± 0.120, which is not significantly different from the average index value of 1.0. Eight of the ten years for which we have more than one fire scar (Table 2) or fire-suppression evidence of multiple ignitions (Table 1) had below-average winter precipitation. Similarly, all 3 years for which we have evidence of early-season fires (1859, 1860, and 1972), had below-average winter precipitation (Fig. 3b).

TABLE 2. CHRONOLOGICALLY SORTED YEARS FOR WHICH A FIRE SCAR FROM *PINUS CONTORTA* SSP. MURRAYAMA WITHIN THE LODGEPOLE PINE FOREST OF MT. SAN JACINTO WAS DENDROCHRONOLOGICALLY DATED. Mean time period between years with fire = 5.0 ± 2.2 years[b]. [a] The number in parentheses for some years is the number of trees scarred during that year; years without parentheses have just one scarred tree. b For the period 1752 to 1886 and for the 1000 ha lodgepole pine forest.

Year	Return interval (yrs)	Year	Return interval (yrs)	Year	Return interval (yrs)	Year	Return interval (yrs)
1752(5)[a]			1		2		3
	5	1786		1822		1863	
1757			3		17		1
	21	1789		1839		1864	
1778			4		2		9
	1	1793		1841(2)		1873	
1779			4		1		8
	1	1797(7)		1842		1881(9)	
1780(2)			1		10		4
	1	1798(2)		1852(2)		1885	
1781			5		7		1
	3	1803		1859(2)		1886	
1784			17		1		24
	1	1820		1860(4)		1910	
1785							

Seasonal timing of fire risk. On average, 78% of all days with evidence of lightning occur after mid-July (Fig. 5). Thus, the natural fire regime of this lodgepole pine forest includes lightning risk that occurs primarily late in or after the growing season.

DISCUSSION

Fire intensity. Given that the thin bark of *P. contorta* ssp. *murrayana* cannot protect trees from fires of moderate or high intensity (Minore 1979; Ryan and Reinhardt 1988), a fire scar on living *P. contorta* ssp. *murrayana* indicates low intensity for that fire. By extension, the abundance of living, fire-scarred *P. contorta* ssp. *murrayana* of Mt. San Jacinto suggests that fires typically burned with low intensity. The exclusively nonserotinous nature of *P. contorta* ssp. *murrayana* of Mt. San Jacinto also indicates a regime of low intensity fires (Brown 1975; Lotan 1976).

At 375 stems/ha, the lodgepole pine forest of Mt. San Jacinto is sparsely stocked and therefore has a highly discontinuous living fuel load. *Pinus contorta* ssp. *murrayana* generally has an open crown

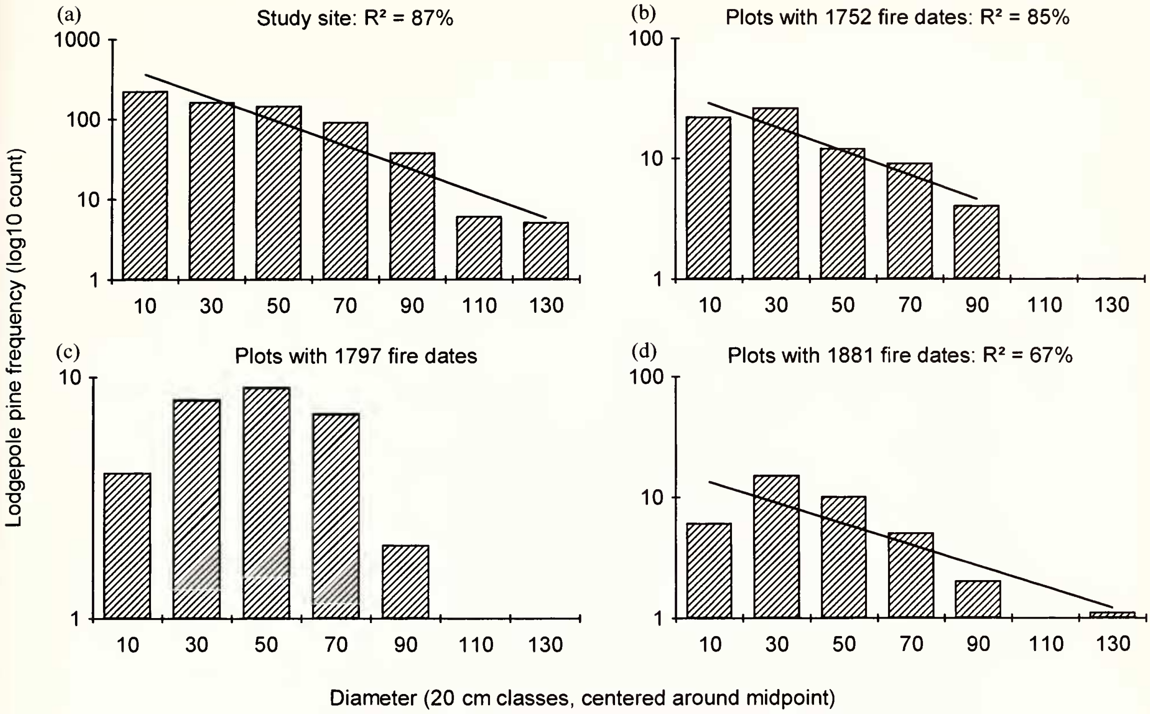

FIG. 4. Size histograms of *P. contorta* ssp. *murrayana* within (a) the entire lodgepole pine forest of Mt. San Jacinto, and plots burned in (b) 1752, (c) 1797, or (d) 1881.

form and foliage with low flammability (Minore 1979), which results in discontinuous ladder fuel loading with little potential for crown fires (Fahnstock 1970). The average ground fuel loading of 18.9 (±2.1) tonnes/ha for the lodgepole pine forest of Mt. San Jacinto is also light, and the Model H fuel type supports fires that typically spread slowly and are not intense except possibly in areas of concentrated downed woody material (Deeming et al. 1977). Furthermore, rock outcrops (common throughout the lodgepole pine forest) act as natural firebreaks that isolate live and dead fuels. This light and discontinuous fuel loading indicates a regime of low intensity fires (Philpot 1977) within the lodgepole pine forest of Mt. San Jacinto.

The forest-wide structure of abundant young trees and exponentially fewer old trees (Fig. 4a) indicates that the lodgepole pine forest of Mt. San

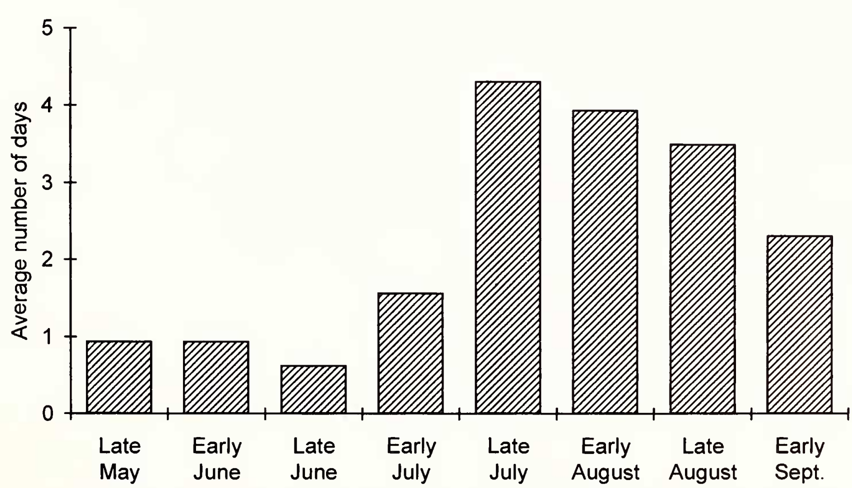

FIG. 5. Frequency of weather with possible lightning somewhere over the lodgepole pine forest of Mt. San Jacinto. Data are summarized from daily records (1965–1974 and 1979–1984) from the Idyllwild and Long Valley stations.

Jacinto is all-aged and self-perpetuating (Lorimer 1980) and that it has not experienced intense disturbances in the past few to several hundred years (Schmelz and Lindsey 1965; Brown 1975; Renkin and Despain 1992). These traits are similar to some Sierra Nevada subalpine forests where *P. contorta* ssp. *murrayana* forms stable populations of zonal dominants on sites beyond the ecological range of more tolerant competitors (Parker 1988) and where canopy or crown fires are virtually absent (Parker 1986). These results and interpretations are also similar to those for some lodgepole pine forests of Yellowstone National Park that have been described as nonpyrogenous, with fire as a disturbance process of low intensity (Despain 1983).

There is some structural evidence for fires of relatively higher intensity. Notably, *P. contorta* ssp. *murrayana* size histograms for the 1797 and 1881 fires are not shaped in a negative exponential pattern, indicating unusually intense disturbances. This is consistent with the fact that many forested ecosystems have regimes of typically low intensity fires with occasional fires of higher intensity (Kilgore 1981).

Fire area. The fact that all suppressed lightning fires were listed as spot (0.4 ha or smaller) suggests natural fires do not typically expand in size quickly. It can be argued, of course, that suppressed fires remained small because they were suppressed. However, remote fires in wilderness areas are inherently difficult to access, and fire crews may have taken more than a day to reach some of these fires, especially before the availability of airborne access. That none of the listed fires grew larger than 0.4 ha before being suppressed suggests that fires typically burn small areas.

Our strategy for field sampling fire scars (transects 200 m apart with grid points every 500 m along each transect) limited our minimum resolvable fire area to approximately 10 ha (Arno et al. 1993). If past fires typically burned areas exceeding 10 ha, we would expect a majority of pairs of adjacent sampling plots to have the same fire date. In contrast to that interpretation, most adjacent pairs of sampling plots have different fire dates, indicating that these fires typically burned areas of less than 10 ha.

The three areas containing several plots with the same fire dates (1752, 1797, and 1881; Fig. 1) have at least two possible interpretations. One is that several small, spatially independent fires ignited and burned during those years. The fire suppression record for 1972 (six fires independent of one another by date or location; Table 1) indicates that this scenario is at least possible because of frequent lightning ignitions. A valid alternative scenario is that a single, large fire burned during those years. Given that higher intensity disturbance processes generally impact larger areas (Sousa 1984) and that forest structure results for plots burned in 1797 and 1881 indicate that those fires may have been relatively intense, it is probable that those fires were relatively large (20 ha or larger).

Frequency. We cannot precisely quantify mean fire interval, defined as the average of all fire intervals between successive fires of a designated area (Romme 1981), because the fire-suppression records and our fire-scar data do not indicate more than one fire date for any particular area. However, if we define the designated area as any single area 10 ha in size (our minimum resolvable fire area), and if lightning ignites fires randomly throughout the entire 1000 ha forest, then a natural fire should burn any designated area only once every 100 years. At this spatial scale, this regime qualifies as one of infrequent (mean fire interval of >25 years) fires of low intensity, similar to other subalpine forests of the Sierra Nevada (Kilgore and Briggs 1972; Kilgore 1981).

In contrast to the mean fire interval of at least 100 years, the mean time interval between fires anywhere in the lodgepole pine forest—not necessarily any particular area—since the mid 18th century is approximately 4 to 7 years (5.2 ± 1.1 years for the fire suppression record of 1945 to 1989, Table 1; and 5.0 ± 2.2 years for the fire scar record 1752 to 1886, Table 2); thus, natural fires occur somewhere throughout the lodgepole pine forest fairly frequently. If this interval analysis is restricted to include only those fires that appear to have burned atypically large areas (as was possible for 1752, 1797, and 1881), then the mean time interval between large fires somewhere throughout the lodgepole pine forest is 64 years, much longer than the 4 to 7 years between fires of any size. The fact that large fires occur infrequently conforms to the general principle that large disturbance events are relatively rare (Sousa 1984).

Relationship of fire with weather. For the lodgepole pine forest of Mt. San Jacinto, evidence that fires, especially most large fires and all early-season fires, occur more commonly during years with below-average winter precipitation is consistent with results from other Southwestern forest ecosystems where natural fires occur more commonly during dry years (Swetnam and Betancourt 1990). These results support the intuitive notion that moisture content of ground and surface fuels is an important factor in fire occurrence and behavior.

Seasonal timing of fire. As indicated by daily weather records and by both the suppression and scar records of fire, lightning and/or fires in the lodgepole pine forests of Mt. San Jacinto commonly occur late in or after the growing season (after mid-July). This temporal pattern of lightning risk is similar to that of the entire Peninsular Range of southern California (Tubbs 1972), but it differs from the pattern found in Southwestern forest ecosystems where lightning fires occur more commonly during June and early July (Baisan and Swetnam 1990).

Management Implications

Given that lightning fires occur fairly frequently somewhere within the lodgepole pine forest of Mt. San Jacinto, State Park Wilderness managers should always expect and be prepared for fires, especially during the latter half of the growing season and during summers preceded by below-average winter precipitation. However, because fires typically burn small areas with low intensity, managers can expect to safely allow most lightning fires to burn naturally, as has been suggested for other forests (Heinselman 1970). Larger fires are possible, of course, and monitoring fires will continue to be prudent, especially for Mt. San Jacinto because of its unique natural resource of very old *P. contorta* ssp. *murrayana.*

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